

The Industry-Developed PV Roadmap

A Framework for U.S. Industry and Technology Leadership

The U.S. photovoltaics industry has the distinction of being the world's leader in research, technology, manufacturing, and markets. During the last several years, though, other foreign interests have recognized the critical importance of this technology and have accelerated their own strategic incentives toward securing dominant global positions. Three key attributes of this electricity source are fueling the intense world interest in photovoltaics:

- **Environment:** PV is truly a clean, emission-free renewable electrical generation technology, with substantial potential and competitiveness in the world's future energy mix.
- **Technology:** PV is elegant, reliable, manufacturable, consumer-friendly, and can be deployed in a wide range of applications.
- **National Interest:** PV is critical to our energy security, strategic technology, and long-term economic growth. As a "distributed" generation source, this technology acts as a network—not a grid—and is much less susceptible to large-scale outages caused by disasters of natural or human origin. It mitigates our dependence on foreign energy supplies, while providing distinct benefits to our domestic economy.

The PV industry recognizes the importance of collaborative planning and R&D partnering to its future vitality—especially because no segment of the indus-

try is currently large enough to guide the entire infrastructure and competitive investments on its own. By developing a "roadmap," the U.S. PV industry will address the critical needs of photovoltaics technology and will ensure U.S. industry leadership over foreign competitors and growing investments by their governments. Our document is a framework that can serve to develop strategic plans for and investments in this technology and business—specifically as a U.S. strategic and national resource.

This "framework" roadmap will evolve into a full roadmap to guide U.S. photovoltaics research, technology, manufacturing, applications, markets, and policy through 2020.

The Vision

"The Vision is to realize a thriving United States-based solar-electric power industry, which provides competitive and environmentally friendly energy products and services that meet the needs and desires of the domestic electric-energy consumer."

In support of this vision, the industry and its partners have generated several key projections, which include annual module shipments strategies for the U.S. PV industry (Figure 1) and cumulative PV shipments for the United States and the world (Figure 2).

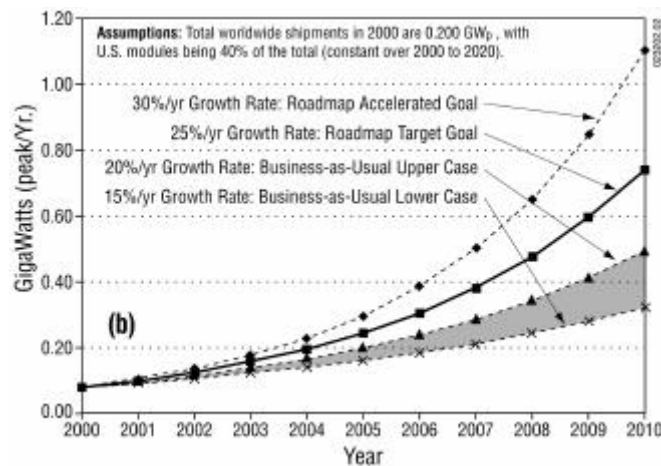
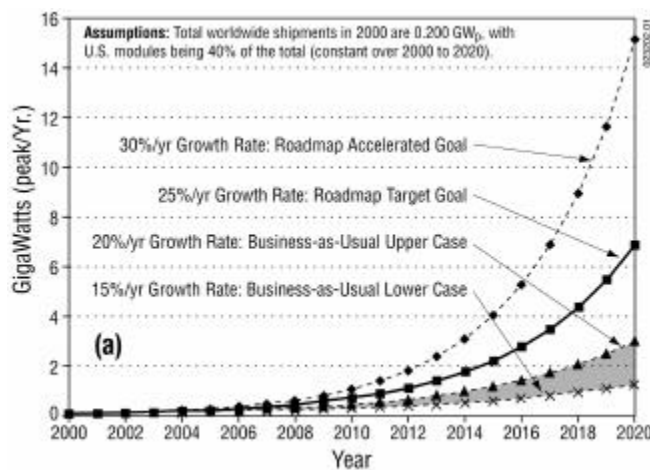


FIGURE 1a & 1b. Growth curves, showing shipments in GW_p as a function of time, for Roadmap annualized growth (25%), accelerated growth (30%), and business as usual (between 15% and 20%). Annualized growth characteristics are compared for the time periods of (a) 2000-2020 and (b) 2000-2010.

Four strategies are the focus for implementing the Vision:

Maintain the U.S. industry's worldwide technological leadership—Photovoltaics is a technologically sophisticated product that is also evolving rapidly. Technological leadership is necessary both for economic competitiveness in PV markets and for PV to reach its potential within the national energy portfolio.

Collaboration and cooperation of industry, government, and educational institutions is paramount to preserving and enhancing this leadership role. With mounting foreign investments and eroding U.S. market share, it is essential to strengthen and expand these relationships to secure our future. This will involve taking our core research, development, and other intellectual resources and integrating them with the U.S. industry's best interests. Furthermore, we must provide sound and well-conceived programs and *sustained* investments that clearly support and guide critical global U.S. industry leadership. Partnering of national laboratories and universities with the U.S. industry is essential.

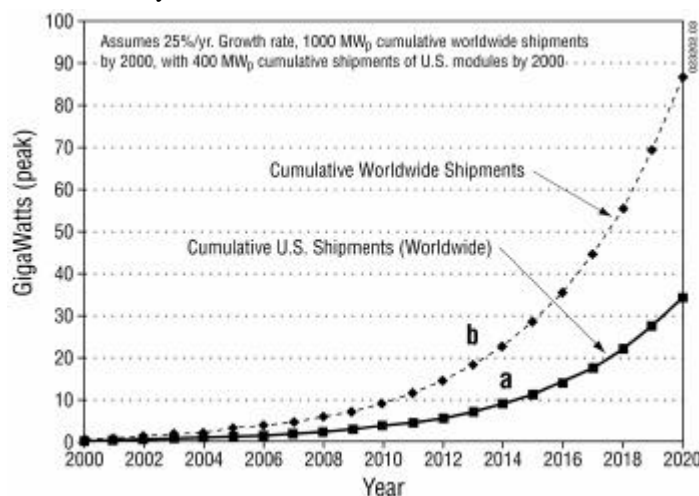


FIGURE 2. Cumulative PV shipments for the (a) United States, and (b) world.

Achieve economic competitiveness with conventional technologies—During the past 25 years, the cost of photovoltaics has come down by several orders of magnitude. Concurrently, the industry has grown at annualized rates of 15%-20%—a growth rate comparable to that of the semiconductor and computer industries, which are in the “hundreds of billions of dollars” business category today. Based on the actual cost of electricity at the point of use, current PV systems are within a factor of 2-2.5 for distributed generation (e.g., residential rooftops). The advantages of PV cited above—environment, technology, and na-

tional interest—provide a unique competitive posture for this technology. Enormous markets will be established for PV as the cost of the technology approaches conventional technologies. This roadmap highlights the route to be taken in reaching peak-watt costs of under \$3 in a timeframe that will ensure this competitive position.

Maintain a sustained market and PV production growth—A sustained growth in PV production capacity and markets will establish PV solar energy as a significant contributor to the nation's energy portfolio. In the United States, peak electrical generation capacity in 1999 is about 800 GW_p.¹ With the projected U.S. PV industry growth in this roadmap (25% per year), about 10% of U.S. peak generation capacity² would be approached by PV by 2030 and would potentially be exceeded in 50 years. In reality, we expect that U.S. demands for electricity will be met by a portfolio of alternatives. We also confidently anticipate that PV will be a major, pivotal part of that portfolio. PV will strongly impact AC distributed generation and DC value applications. It will provide a significant portion of the new U.S. electricity peak generating capacity between 2020 and 2030. In meeting the roadmap's cost goals, the industry will approach \$10 billion per year—creating thousands of high-value jobs for the domestic markets alone and enormous environmental benefits within the timeframe of the roadmap.

Make the PV industry profitable and attractive to investors—The aggressive growth in this roadmap will require considerable private investment. The PV industry must be profitable and attractive to investors to garner the levels of required investment. In attaining the market and technological goals of this roadmap, profitability and substantial investment can be realized. To grow into the predicted \$10 billion-per-year U.S. business, we must establish strategic guidance and provide foundational funding now. With this roadmap, the industry will be profitable, the investments of the private-sector will be secured, and the nation will have an industry that clearly leads the world in production, deployment, technology, and domestic economic benefit.

Beyond these four strategic thrusts, photovoltaics and this roadmap provide us with a path toward becoming better stewards of our environment. Photovoltaics is a viable option to improve the quality of life of our world citizens by deploying secure, reliable, and clean energy to power our homes, factories, and institutions.

Attention to this roadmap is crucial to ensure a long-term strategic vision. Attaining the goals is paramount to maintaining U.S. technical and manufacturing leadership.

Directions, Goals, and Targets

This roadmap focuses on maintaining and building the global leadership of U.S. industry. A major target is the domestic markets. With a projected growth of 25% per year in the U.S. PV industry, the cumulative installed PV will increase substantially from its 1998 level of 60 MW_p. The U.S. generation capacity grows at 1%-3% per year, and this incremental capacity addition is expected to be about 21.5 GW in 2020.

Addressing the new (added) peak electrical generating requirements, the following “**endpoint**” is projected for photovoltaics in 2020:

“For the domestic photovoltaic industry to provide up to 15% (about 3,200 MW_p) of new U.S. peak electricity generating capacity expected to be required in 2020. The U.S. cumulative PV shipments will be about 30 GW_p at this time.”

Non-domestic markets are significant and represent a substantial portion of the sales—especially in the near-term periods of this roadmap. In fact, when preparing the details, we will need to account for the influence of international and other high-value markets in the near-term expansion of the industry, in advance of large-scale domestic markets.

International markets are already being addressed and will continue to be a major part of the U.S. PV company portfolios. However, the importance of PV technology to the interests of the United States makes it imperative to develop a plan that clearly identifies our domestic markets as a major target for growth, sales, and consumer use.

Figure 3 projects U.S. manufactured PV modules installed in domestic applications as a function of time. If we do not focus on and develop U.S. markets—that is, if the percentage of U.S. shipments between domestic and international remains at the current level—then the 3.2 MW_p goal in 2020 cannot be met, unless an unlikely total growth rate of 50% is attained. Without this focus on domestic markets, which complements the global marketplace, the United States will lose—to foreign competition—its opportunity to serve its citizens and own national interests.

The **overall goals** for the U.S. photovoltaics industry align with the 25% annual production growth rate. This rate, represented in Figure 1, is compared to an accelerated scenario of 30% and business-as-usual scenarios of 15% and 20%.

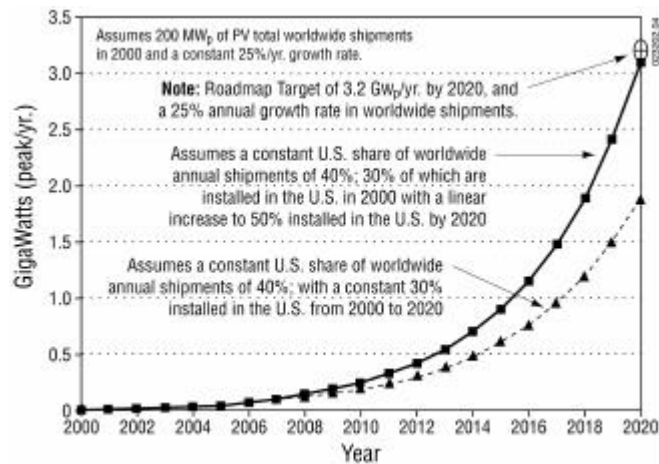


FIGURE 3. Projections of U.S. manufactured PV modules installed in U.S. domestic applications, for a constant 30% U.S. market and a linear increase from 30% to 50% from 2000 until 2020.

The **specific goals** for the roadmap are categorized in two major industry target areas:

■ **Total installed (annual) peak capacity**—This will be at least **6 GW_p** installed worldwide by the U.S. industry during 2020, of which **3.2 GW_p** will be used in **domestic** installations. The industry expects the application mix to be:

- 1/2 AC distributed generation
- 1/3 DC and AC value applications
- 1/6 AC grid (wholesale) generation.

The installed volume will continue to increase, exceeding 25 GW_p of domestic photovoltaics during 2030. In 2020, the cumulative installed capacity in the United States will be about 15 GW_p, or about 20% of the 70 GW_p expected cumulative capacity worldwide.

■ **Costs**—The cost to the end-user (including O&M costs) will be \$3 per watt AC in 2010 and will approach \$1.50 per watt AC in 2020. The total manufacturing costs are projected to be 60% of the costs of the system.

To reach these goals, the PV industry and its partners have identified four critical **Technology Development Areas**, around which the roadmap is fashioned. These areas are:

- Markets and Applications
- PV Components, Systems and Integration
- Manufacturing, Equipment, and Processes
- Fundamental and Applied Research

Coordinated Approach and the Road Ahead

The roadmapping process is now to build the details around this framework, specifying the short- and mid-term goals and objectives and the technology pathways to meet these long-term roadmap goals. The success in 2020 of achieving the vision and these goals will be a hundredfold growth—over 2000 levels—in domestic markets and the U.S. industry. The roadmap will set the stage for further ramping up of the use of this valuable renewable resource beyond 2020, providing significant portions of U.S. and world electricity generation by an environmentally clean, reliable, and competitive energy source.

Addressing the issues and achieving success with the roadmap goals is not a matter of choice. The U.S. industry and its partners must be ready to meet the ever-growing demand for consumer energy products and sources by making the right choices today, revisiting the technology guidance system frequently, and readjusting our direction in response to technology advancements and market needs. Research implemented today allows for choices in products and product availability tomorrow. Resources invested today provide the foundation for long-term success.

The Photovoltaic Industry Roadmap is a guide, and its success depends on the direction, resources, best scientific and technological approaches, use of the best and most advanced technologies, and continued

efforts of the “best and brightest” among the industry, federal laboratory, and university partners. The framework roadmap sketched here provides a basis for more detailed planning and a picture of the needs and requirements for photovoltaics research, technology, manufacturing, applications, markets, and policy through 2020—developed by the U.S. industry as a guide for the efforts of the U.S. PV Program. We desire to meet the scientific challenges, fend off growing competition from foreign interests, and provide the nation with a technology that is critical to environmental and national interests. Therefore, we strongly urge support of these goals by their adoption in the technical direction of the U.S. PV Program and by the funding required to realize their success.

NOTES

- ¹ *Annual Energy Outlook 1999*, DOE/EIA-0383(99), Energy Information Administration (Dec. 1998), p. 125, shows 776 GW_p “net summer capability” for year 2000.
- ² Comparisons of the conventional U.S. *peak* electrical generation capacities and the PV *peak* generation capacities refer to “summer capability” during peak summer-time conditions (mid-day, bright sunshine), when PV modules can produce electrical power according to their peak (e.g., GW_p) ratings.

This framework PV Industry Roadmap is respectfully submitted by the following representatives of the U.S. photovoltaics industry and strategic partners:

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